ENVIRONMENTALLY INDUCED VARIATIONS IN COTTON FIBER MATURITY AND RELATED YARN AND DYED KNIT DEFECTS

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Abstract

Quantitation of fiber quality at individual boll, locule and seed levels revealed wide variations in fiber maturity, *i.e.*, circularity, fineness, and micronAFIS, that were not evident in composite fiber-quality estimates at the bale level. Decreased fiber maturity and uniformity correlated with environmental conditions that increased the number of long-fibered motes [underweight seeds bearing normal-length fiber]. Upland fiber maturation-rate equations [derived from circularity and micronAFIS] estimated mote-fiber physical maturities to be equivalent to maturity of fibers harvested 27 to 31 days after flowering. Environmental factors that increased mote frequency or retarded fiber-wall thickening increased the number of fiber immaturity point sources within composite fiber maturity estimates. Decreased fiber maturity and uniformity related to these point sources was not apparent in composite fiber-quality estimates, but point-source variations in fiber maturity correlated with reduced dye uptake and yarn linear density. The small-sample capabilities of AFIS-F&M [Advanced Fiber Information System Fineness and Maturity module], validated by quantitation of primary:secondary cell wall ratios with x-ray fluorescence spectroscopy [Ca-XRF], was invaluable for quantitation of fiber maturity factors needed for fiber quality and processing predictors. Refinement and combination of fiber-quality models with growth-environment and fiber-processing models will allow prediction of processing defects and benefit cotton producers, processors, and consumers.

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Introduction

Each spring, cotton producers plant those varieties that have exhibited the highest yield and fiber-quality potentials under *normal* growing conditions. However, every growing season presents a unique combination of *controlled* inputs [fertilization, planting date, irrigation] and *uncontrolled* weather conditons [temperature, rainfall, and insolation]. Computer models of whole-plant growth are used to optimize producer-controlled inputs and to predict yield, but predictive models that relate weather and production practices to levels and uniformity of fiber quality and, particularly, to fiber maturity are not yet available.

The *quality* of the growth environment directly affects the *quality* of a cotton plant and of bolls and fibers which develop in that environment. Further, the fruiting site of a boll and the locule position of a seed represent unique combinations of temperatures, light, and metabolic resource allocations. Such point-source environments create point-sources of cotton fiber quality at the boll, locule, and single seed levels. Thus, bale-average fiber quality is the composite of a range of point-source fiber qualities, and processing predictions based on bale-average fiber-quality estimates are no more reliable than a state-wide weather report of annual temperature and rainfall is in predicting the quality of a week spent in one city in that state.

Periodic variations in cotton growth environments are measured instrumentally, and the data are incorporated in cotton production expert systems for yield prediction. Comparable instrumental fiber-quality quantifications by fruiting site, locule or seed require rapid, reproducible, small-sample particle-sizing capabilities that are currently found only in the Zellweger-Uster Advanced Fiber Information System [AFIS] equipped with the commercial Length and Diameter [L&D] and prototypic Fineness and Maturity [F&M] modules. This report describes the use of AFIS-F&M, correlated with an x-ray fluorescence spectroscopy assay of fiber primary:secondary wall weight ratios, in boll-, locule- and seed-level quantitations of fiber micronaire [as micronAFIS], cross-sectional area, and circularity [degree of fiber wall thickening]. Correlations found among levels and uniformity of fiber maturity and growth-environment variations during fiber development are described, as are relationships detected between fiber maturity and yarn strength and dye uptake.

General Materials and Methods

Data discussed here were drawn from five separate field and greenhouse studies of the interactions between growth environment and fiber quality, specifically fiber physical and physiological maturity [Table 1]. Fibers of one Pima and eight Upland varieties, field-grown in 1992 or 1993 in South Carolina, Mississippi, or coastal Texas were assayed on an individual boll, locule, or seed level. The one constant factor in the studies was use of AFIS-F&M for the quantitation of fiber micronaire, cross-sectional area, and circularity.

During 1992 in South Carolina, spring and early fall temperatures were lower than normal; and rainfall was not evenly distributed, 63% of the total 589 mm falling between mid-August and a killing frost on 20 October. In the study comparing in-row microirrigation [IR] with natural rainfall [RF], the effective duration of irrigation corresponded with the seed and fiber-filling periods of the first and second fruiting positions on branches 6 through 8 of irrigated PD3 and to the first and second fruiting positions on branches 5 through 10 of the rainfed PD3. The boll load on irrigated plants was shifted to higher branches and outer branch positions, compared to the load on the rainfed plants.

Results and Discussion

Environment modified mote frequency and distribution. As seen in Table 2, irrigation significantly altered the levels and distribution among fruiting positions of PD3 micronAFIS [a micronaire analog calculated by AFIS-F&M]. Before fiber quality analysis, each locule was roller-ginned separately; and all fiber from a single PD3 locule constituted one statistical replicate. A similar pattern of irrigation-related shifts among fruiting positions was found in PD3 fiber circularities and cross-sectional areas.

Mote-fiber maturity was significantly lower. AFIS-F&M quantifies physical fiber maturity as fineness [cross-sectional area] and circularity [degree of fiber-wall thickening], components of micronaire, calculated by AFIS-F & M micronAFIS. Fiber circularity [θ] and the circularity distribution function, Immature Fiber Fraction [IFF, % fibers for which $\theta < 0.250$] were particularly sensitive to environmental factors that modified micronAFIS. The IFF distributions for 1992 rainfed and irrigated PD3 are shown in Table 3.

Lower maturities of fibers from lower branches of the irrigated PD3 plants coincided with increases in the number of motes [small, underweight seeds bearing fiber of near-normal length]. Relative mote frequencies in bolls from irrigated and rainfed PD3 plants are shown in Table 4.

Physiological causes of increased mote frequency in irrigated PD3 bolls are still under investigation, but the correlation between high mote counts and high IFF is obvious when Figures 1b and 2a are compared. If mote-fiber physical maturity differs significantly from the maturity of fiber from normal-weight seeds, then increased mote frequency would skew both the level and variability of composite fiber maturity.

This hypothesis was tested by collecting both long-fibered motes and normal seeds from 1992 DPL51 bolls grown in coastal Texas. Chronological ages of DPL51 motes and seeds were identical, and the average length of both mote fibers and normal DPL51 fibers was 24.6 ± 0.8 mm. Weights of motes plus fiber fell into three classes, 7 to 20, 21 to 35, or 36 to 59 mg. Motes were collected from three locule regions, *i.e.*, apical [positions 1 to 3], medial [positions 4 to 6/7], or basal [positions 7/8 to 10+]. Mean DPL51 seed-cotton weight was 147.1 ± 9.3 mg. The fibers from both motes and normal seeds were finger-ginned and analyzed by AFIS-F&M. MicronAFIS values of mote and normal fibers are compared in Table 5. The mote-fiber mean micronAFIS was less than 40% that of normal DPL51 fibers.

Compared to normal DPL51 seeds, long-fibered motes, regardless of weight or location in the locule, were point-sources of low micronaire. Mote fibers, which are characterized by normal length and near-normal fineness, would gin and process with normal fibers from full-weight seeds and, thus, lower the composite micronaire. Mote fiber cross-sectional areas were 62% of the mean for normal DPL51 fibers [$A(n) = 136.05 \pm 11.24\ \mu m^2$]. Mote Immature Fiber Fractions were 600% those of normal fibers; even though mote circularity was 62% of the normal seed mean. The fiber circularities of mote and normal fibers are compared in Table 6. The "mote effect" is more pronounced in Immature Fiber Fraction and micronaire than in fiber cross-sectional area and fineness.

Mote fiber immaturity and fiber wall thickening. The low circularities of mote fibers resulted from decreased deposition of cellulose in fiber secondary cell walls which resulted in a lower degree of fiber wall thickening. This interpretation was based on AFIS-F&M data validated by quantitaation of fiber-wall calcium content by weight through x-ray fluorescence spectroscopy [Ca-XRF]. The high calcium concentrations associated with the primary cell wall pectic components and the negligible calcium content of the highly cellulosic secondary wall make calcium a specific marker for primary wall and dilution by weight of primary wall calcium during secondary wall cellulose deposition a physio-chemical test of relative fiber maturity. This calcium/primary wall dilution effect was followed over time in DPL5415, DES119, and Pima S-6; and varietal fiber maturation rate equations were derived through regression analyses of the Ca-XRF data [Fig. 3b].

The Upland cotton regression equations in Table 7 estimated a relative mote chronological age between 35 and 42 dpa, based on DPL51 mote Ca-XRF date. Pima S-6 Ca-XRF regression equations and AFIS-F&M data reflect the naturally higher fiber fineness and length of *Gossypium barbadense*. Mean 56-dpa Pima S-6 Ca-XRF was 1101 ± 70 $mgkg^{-1}$. Pima data were included as inter-specific comparisons of Ca-XRF fiber maturity quantitations.

Physio-chemical fiber maturities determined by Ca-XRF correlated well with physical maturities quantified as AFIS-

F&M micronAFIS and circularities. In the same way that Ca-XRF regression equations and data were used to determine the relative maturity of the DPL51 mote fibers, maturation rates derived from regression equations describing the changes over time in Upland circularity or micronAFIS were used to assign relative mote-fiber physical maturities. Based on micronAFIS maturity equations for Upland cotton varieties, relative chronological maturities of fibers from DPL51 long-fibered motes and seeds ranged from 18 to 60 dpa [Table 8]. When equations based on Upland micronAFIS were used, the estimated mean chronological age of DPL51 mote fibers was 27 dpa, compared to 56 dpa, the similarly calculated chronological maturity of the normal field-grown fibers.

Similar estimates of fiber chronological age were made using mote and fiber circularities. On that basis, mote fiber chronological ages ranged from 21 to 36 dpa, with a mean chronological maturity of 31 dpa. The normal-fiber chronological maturity, based on circularity, was 58 dpa. The corresponding IFF range was 20 to 41% for the DPL51 motes, and the mean IFF for normal DPL51 seeds was less than 5%.

Fiber immaturity modified yarn properties. Motes represent a major source of physically immature fibers that can increase processing defects when the mote-fiber lengths approximate those of normal fibers so that mote fibers gin and spin like normal, mature fibers. Suboptimal growth conditions, *e.g.*, cool temperatures, cloudy skies, early frosts, also decrease fiber maturity.

In a 1991 planting date study in South Carolina, four Upland varieties, DPL20, DPL50, DPL90, and DPL5690, were planted on April 17 [early], May 1 [normal], and May 15 [late]. Twenty-three weeks after planting, the bolls from each planting date were harvested and pooled, according to variety and planting date. Fiber was saw-ginned, analyzed by AFIS, and spun into yarn. Planting date significantly modified fiber circularity, cross-sectional area, and micronAFIS [Table 9]. The association of lower micronAFIS with later planting was also seen in the 1992 planting date study, but there were significant environmentally induced differences between 1991 and 1992 micronAFIS, circularities, and cross-sectional areas. Planting date and year had no effect on staple length, which was dependent on genotype.

Fiber circularities decreased from early to late planting in all varieties in both years. When Upland fiber maturation rate equations based on θ were used to calculate relative maturities of fibers from the different varieties and planting dates in Table 9, fiber maturities ranged from 38 dpa [DPL20, late planting, 1991] to 51 dpa [DPL5690, late planting, 1992]. Since the time elapsed between planting and harvest was the same for all planting date treatments, the differences in fiber maturity within varieties were related to the unique growth environments under which fibers from each planting date developed.

Variations in fiber circularity [and IFF] among varieties and planting date treatments correlated with yarn strength and tenacity [g/tex]. The closest correlation [$r = 0.756$] was found between 1991 circularity and g/tex [Table 10]. The corresponding IFF percents ranged from 16% [DPL20, late] to 10% [DPL5690, normal]. Fiber circularity and IFF were more closely related to yarn strength and tenacity than were cross-sectional area and micronAFIS. Fiber circularity was also closely and linearly correlated with yarn elongation [$r > 0.883$]. MicronAFIS was more closely and linearly related to yarn elongation percent than to tenacity.

Fiber cross-sectional area did not correlate with either yarn elongation or tenacity. Instead, yarn elongation and tenacity depended on the Short Fiber Contents [SFC] by weight and by number [calculated by AFIS-L&D]. Like staple length, SFC [% fibers< 12.5 mm long] was genotype-dependent and not significantly affected by environmental factors that modified fiber maturation rates. Planting date had no effect on either fiber length or Short Fiber Content of the four DPL varieties examined. In 1991, varietal SFC by weight ranged from 13% [DPL5690 and DPL90] to 16% [DPL20 and DPL50]. The corresponding yarn tenacities were 14 g/tex [DPL20 and DPL50] and 17 g/tex [DPL5690 and DPL90]. Crop year had no effect on SFC, and no interactions relevant to either yarn linear density or elongation percent were found between crop year and genotype.

Immature fibers and reduced dye uptake. Cross-sectional area was not related to dark-blue dye uptake by knits, as measured on the Hunter Colorimeter *L* [white-black axis] or *b* [yellow-blue axis] scales. However, both micronAFIS and fiber circularity were closely related to those shade and hue indicators [$r > 0.800$]. Interactions between planting date, fiber maturity, and lightness of color are apparent in a plot of the mean [front-back] *L* values [Table 11].

Blue-dyed knits made from the least mature [late-planted] fibers were lighter in color than knits made from the more mature [early-planted] fibers. Varietal differences in dye uptake were most apparent in the least mature fibers from the late plantings, and dye uptake by DPL20 was least, regardless of planting date. The correlation between increasing fiber circularity and decreasing fabric reflectance was quite close [*L* mean $r > 0.830$ in both 1991 and 1992], and the relationships between decreasing reflectance and increasing micronAFIS were also close in both crop years.

Vector analyses of Hunter Colorimeter *a* [red-green] and *b* scale data was used to quantify color differences between undyed [greige] and blue-dyed knit fabrics. *Chromaticity*

Difference relates the differences in dyed and undyed fabric colorimeter readings along the *a*, and *b* axes according to the equation:

$$\text{Chromaticity Difference} = [(a_{dyed} - a_{undyed})^2 + (b_{dyed} - b_{undyed})^2]^{1/2}.$$

Planting date had a significant effect on the Chromaticity Difference in the blue knits under discussion [Table 12]. Independent of year and variety, Chromaticity Difference was higher in the more mature fibers from the earliest planting date; and Chromaticity Differences were significantly higher in 1992 than in 1991. Chromaticity Difference was more closely correlated to cross-sectional area and micronAFIS than with circularity and Immature Fiber Fraction.

A similar calculation of the three-dimensional hypotenuse connecting the *L*, *a*, and *b* Hunter Colorimeter readings of a knit can be used in calculating the Total Color Difference. In both 1991 and 1992, the least mature fibers took up less dye than the more mature fibers from the earlier planting dates [Table 13].

Composite fiber maturity concealed significant fiber immaturity that was detected by dye tests. Cotton bolls and fibers from early, normal, and late plantings experienced the same environmental conditions but fiber-quality modifying events occurred at different boll and fiber developmental stages. Fibers from each field block were harvested and ginned together before collection of grab samples for AFIS and spinning studies. Thus, AFIS fiber-quality quantitations were composite values, as were data from yarn and dyed-knit tests. In the planting-date study, fiber-quality variations among field blocks were quantified, but variations among plants, among fruiting positions, or within bolls were not. The persistence of differences in yarn properties, dyed-knit reflectance, and chromaticity through the many compositing and blending processes from harvest through finished fabric indicated that point-source and composite fiber qualities are both important in determining the number of yarn and dye defects.

In a water-stress greenhouse study of DPL50 fiber quality, fibers were harvested after boll opening and roller-ginned before analysis by AFIS. Plant position in the greenhouse [east or west side] was also a significant factor. Fibers from four plants were pooled according to treatment [control or water stress] and plant position, without consideration of flowering date or fruiting position. The ginned fibers from all plants representing each position X treatment combination were blended and divided into fifteen replicates for dye-uptake testing with fast red dye. The AFIS-F&M fiber maturity parameter means and the mean frequencies of white [undyed] areas in the dyed fiber webs are compared in Table 14.

The AFIS-F&M means did not differ among the position X treatment combinations, but the white speck frequency means were significantly different [$P = 99.99\%$]. Drought stress decreased fiber dye-uptake uniformity and increased the number of dye defects found in the webs. When fiber quality parameters were examined on an individual plant or by vertical fruiting zone [low, middle, high] basis, pooling of fibers concealed point-source variations in fiber maturity that were easily detected and counted on the dye-test webs.

Conclusions

An individual cotton boll and the fibers within develop and mature in an environment unique to that boll. Both subtle and marked variations in temperature, sunlight, and water and metabolic resource allocations interact with natural variations in fiber developmental patterns to decrease further fiber uniformity within a bale. Bale-average fiber quality is a poor predictor of fiber processing properties because such composite estimates of fiber quality and maturity do not describe the *range* of fiber-quality point-sources that contribute to the composites. Reliable estimates of relative fiber maturity are particularly important for predictions of dye defects because dye uptake [and barré and white speck formation] depend on individual, not bulk, fiber properties. Variations in point-source fiber maturities also modify yarn linear density and elongation.

Reliable prediction of spinning and dye defects requires modeling of environmental effects on fiber quality, particularly maturity, below the bale level. Reproducible small-sample fiber-quality quantitation are fundamental to such models and can be obtained with AFIS-F&M, combined with Ca-XRF when validation of degree of fiber wall thickening is needed. AFIS fiber-quality quantitations can be made at the seed, locule, or boll levels, and these data can be used in developing fiber maturation rate equations and other fiber-quality predictors appropriate for integration with whole-plant growth models used by producers and fiber-processing models being developed by the textile industry.

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Trade names are necessary to report factually on available data. The USDA neither guarantees nor warrants the standard of the product or service, and the use of the name USDA implies no approval of the product or service to the exclusion of others that may be suitable.

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Table 1. Studies from Which AFIS-F&M Maturity Quantifications Were Drawn.

Study	Year	Location	Cotton Varieties	Other Fiber Quality Tests
Microirrigation	1992	SC	PD3	- - -
Motes/ drought	1992	Coastal TX	DPL51	Ca-XRF
Water Stress	1994	SRRC [greenhouse]	DPL50	Red dye uptake White speck count
Fiber maturation rates X environment	1992 1993	MS	DPL5415 DES 119 Pima S-6	Ca-XRF
Planting date X genotype [maturity rating]	1991 1992	SC	DPL20 DPL50 DPL5690 ACALA 90	Single-end strength and evenness yarn tests Hunter colorimeter *Greige knit *Blue-dyed knit

Table 2. Fiber maturity [as micronAFIS] at first and second positions of branches 7 through 15 of PD3 grown in South Carolina. Each mean represents micronAFIS values from 12 roller-ginned locules. Means of four commercial PD3 micronaire determinations were: IR = 3.8 ± 0.1; and RF = 4.2 ± 0.2.

	Irrigation Treatment Rainfed = RF; In-row microirrgation = IR.			
	micronAFIS			
Fruiting Branch	RF-P1	RF-P2	IR-P1	IR-P2
7	6.52	4.23	4.09	3.70
8	2.88	4.58	3.85	2.18
9	5.36	5.17	2.28	3.36
10	4.67	4.59	3.75	3.78
11	4.36	4.67	3.57	3.89
12	4.46	3.18	5.21	3.67
13	4.01	3.96	2.42	2.73
14	2.5	3.90	---	---
15	---	---	5.20	3.10

Table 3. Fiber maturity as Immature Fiber Fraction [IFF] at first and second positions of branches 7 through 15 of PD3 grown in South Carolina. Each mean represents IFF of 12 roller-ginned PD3 locules.

	Irrigation Treatment Rainfed = RF; In-row microirrgation = IR.			
	IFF, %			
Fruiting Branch	RF-P1	RF-P2	IR-P1	IR-P2
7	4.49	9.30	10.94	13.66
8	20.53	9.73	16.49	36.51
9	8.52	8.16	26.43	18.1
10	11.39	14.28	19.63	12.49
11	11.45	8.97	20.19	12.85
12	14.00	21.59	6.21	12.26
13	13.09	12.27	30.59	19.61
14	27.76	13.27	--	---
15	---	---	7.91	13.85

Table 4. Frequency and distribution of motes at first and second positions of branches 7 through 15 of PD3 grown in South Carolina.

	Irrigation Treatment Rainfed = RF; In-row microirrgation = IR.			
	Mote Frequency			
Fruiting Branch	RF-P1	RF-P2	IR-P1	IR-P2
7	2.7	2.0	3.0	1.0
8	1.3	2.0	10.7	7.0
9	4.0	1.0	8.7	6.3
10	2.6	1.8	4.4	4.5
11	2.7	1.0	5.0	3.0
12	1.3	3.8	2.6	2.4
13	2.2	3.3	4.0	4.0
14	3.0	5.3	2.8	---
15	4.3	---	3.6	2.7

Table 5. DPL51 micronAFIS values of fiber from three weight-classes of long-fibered motes and from normal seeds. Data are means of 3 AFIS-F&M analyses of finger-ginned fiber. Mean mote micronAFIS = 2.39 ± 0.47; mean normal DPL51 micronAFIS = 6.06 ± 0.44.

Mote Weight class	Position in locule Apical	Medial	Basal	Normal Seed [147.1±9.3 mg]
	micronAFIS			
High [36 to 59 mg]	2.904	2.867	2.503	6.570
Middle [21 to 35 mg]	2.329	2.662	2.723	6.096
Low [0 to 20 mg]	1.364	2.317	1.908	5.502

Table 6. Degree of fiber wall thickening as circularity from three weight-classes of long-fibered motes and from normal seeds. Means represent three AFIS-F&M assays of finger-ginned fiber. Mote mean theta = 0.377 ± 0.038, corresponding to IFF = 27.8 ± 7.1%. Normal mean theta = 0.611 ± 0.026 where IFF = 4.8 ± 1.5%.

Mote Weight class	Position in locule Apical	Medial	Basal	Normal Seed [147.1±9.3 mg]
	Circularity, theta			
High [36 to 59 mg]	0.412	0.420	0.392	0.640
Middle [21 to 35 mg]	0.368	0.397	0.399	0.617
Low [0 to 20 mg]	0.299	0.374	0.328	0.576

Table 7. Fiber maturation rates of DPL5415, DES119, and Pima S-6 from regression equations comparing Ca-XRF versus time [DPA]. All linear regressions were significant. Average Ca-XRF weight ratio of mature [56-DPA] fibers of Upland cotton varieties was 825 ± 105 mg/kg. Normal DPL51 Ca-XRF was 779 ± 48 mg/kg, comapred to the mean mote Ca-XRF of 1611 ± 336 mg/kg.

	Regression slope [rate]	Regression Intercept	Regression Coefficient [*r*]
DES 119 7/92	-41.41	3240.4	-0.920
DPL 5415 7/93	-15.13	1648.8	-0.807
Pima S-6 7/92	-24.97	2449.5	-0.827
Pima S-6 7/93	-6.782	1506.9	-0.451
DPL 5415 8/93	-19.67	1913.5	-0.814
Pima S-6 8/93	+3.368	1429.3	+0.095

Table 8. Chronological maturities of DPL51 fibers from long-fibered motes and normal-weight seeds. Maturities shown were derived from the Upland micronAFIS maturation rate equations and from AFIS-F&M micronAFIS data.

Mote Weight class	Position in locule Apical	Medial	Basal	Normal Seed [147.1±9.3 mg]
	Estimated Mote Chronological Maturity, DPA			
High [36 to 59 mg]	30.6	30.3	27.3	60.0
Middle [21 to 35 mg]	25.9	28.6	29.1	56.2
Low [0 to 20 mg]	18.3	25.8	22.5	51.4

Table 9. Fiber maturity [as micronAFIS] of four cotton varieties planted on 4/17/91, 5/1/91, or 5/15/91 in South Carolina.

Plant date	DPL 20	DPL 50	DPL 90	DPL 5690
	micronAFIS			
Early 4/17/91	4.15	4.56	4.73	4.66
Normal 5/1/91	3.84	4.54	4.68	4.85
Late 5/15/91	3.68	4.04	4.37	4.39

Table 10. Yarn tenacity [linear density or g/tex] of four cotton varieties planted on 4/17/91, 5/1/91, or 5/15/91 in South Carolina.

Plant date	DPL 20	DPL 50	DPL 90	DPL 5690
	Yarn tenacity, g/tex			
Early 4/17/91	14.17	14.95	15.94	16.11
Normal 5/1/91	13.74	14.75	16.26	15.79
Late 5/15/91	13.51	14.11	15.44	15.36

Table 11. Reflectances [relative whiteness] of blue-dyed knit fabrics made from fibers of four cotton varieties planted on 4/17/91, 5/1/91, or 5/15/91 in South Carolina.

Plant date	DPL 20	DPL 50	DPL 90	DPL 5690
	Reflectance, L			
Early 4/17/91	+22.59	+22.39	+22.25	+22.16
Normal 5/1/91	+22.95	+22.35	+22.16	+22.29
Late 5/15/91	+23.33	+22.96	+22.76	+22.54

Table 12. Chromaticity Differences in blue-dyed knit fabrics made from fibers of four cotton varieties planted on 4/17/91, 5/1/91, or 5/15/91 in South Carolina.

Plant date	DPL 20	DPL 50	DPL 90	DPL 5690
	Chromaticity Difference, Delta C			
Early 4/17/91	25.06	25.76	26.65	26.80
Normal 5/1/91	24.67	25.58	26.93	26.52
Late 5/15/91	24.46	25.01	26.21	26.30

Table 13. Total Color Differences in blue-dyed knit fabrics made from fibers of four cotton varieties planted on 4/17/91, 5/1/91, or 5/15/91 in South Carolina.

Plant date	DPL 20	DPL 50	DPL 90	DPL 5690
	Total Color Difference, Delta E			
Early 4/17/91	69.34	68.98	69.15	69.45
Normal 5/1/91	69.98	69.87	69.86	70.09
Late 5/15/91	70.35	69.96	70.18	70.73

Table 14. Comparison of AFIS-F&M fiber maturity and frequency of white specks in ginned fiber webs of greenhouse-grown DPL50. [AFIS-F&M data are means of four determinations; web white speck counts are means of 15 replications.]

	East-Control	West-Control	East-Drought	West-Drought
Theta	0.593 ±0.020	0.612 ±0.011	0.581 ±0.017	0.591 ±0.037
A[n]	142.7 ±3.1	144.2 ±3.2	139.6 ±4.5	142.7 ±7.3
micronAFIS	6.12 ±0.27	6.33 ±0.22	5.91 ±0.32	6.15 ±0.48
# Web White specks	2.9 ±1.5	3.8 ±1.2	6.2 ±8.2	15.9 ±23.9